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The PI and a student have been working in close consultation with researchers at AFRL/DEL on developing a geometric view of the optically injected laser problem. An interesting source of complex behavior (chaos) has been uncovered. This complicated behavior is the result of parametric sweeping across a resonance. From the experimental and practical perspective this is a natural scenario and the possibility of implementing it experimentally has been discussed. This is potentially important in applications (for instance, communications) as the chaotic behavior can be precisely controlled and understood in terms of phase-shifting. Some recent work has revealed a direct source of chaotic behavior in the optically injected semiconductor laser equations.

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Dynamical Systems Techniques in Nonlinear Optics
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Final Report

The problem of pulse propagation in nonlinear optical media is a key issue in an increasingly important technology. Many problems in pulse propagation in optical media lead to the study of pulse solutions for coupled nonlinear Schroedinger equations. Apart from some special cases, the integrable theory is not useful and new techniques are needed. A student of Jones, Alice Yew, has shown that multiple pulses in a chi-2 medium are present at appropriate parameter values but are NOT stable. It appears, in fact, that all multiple pulse solutions of coupled NLS systems are unstable. Most people agree that this is probably the case, but nobody knows why. We have an approach that promises an understanding of these instabilities. The problem then will be to figure out how to stabilise them, but a clear understanding of the instability will, I believe, indicate a solution. This promises many applications as researchers strive to increase the bit-rate in nonlinear optical communication systems. Stabilising factors generally need more study; for instance, the non-local effect suggested by Menyuk as stabilising remains mysterious. If such effects can be handled in a stability theory, then the possibility of their adding a stabilising force to the multiple pulses of coupled NLS is an exciting prospect.

Given the inevitability of interaction between pulses in some systems a comprehensive theory is needed for assessing the effect of these interactions. Jones' postdoc, Bjoern Sandstede, developed a theory of pulse interactions in disspiative systems. We need to extend this to the conservative, or at least near conservative, case. As an extension of the stability theory of multiple pulses, this might be extremely useful as the underlying pulses could be imagined as being at any mutual separation distance. The applicability of this pulse theory is then greatly enhanced.

In collaboration with Kath, Sandstede and Alexander, Jones is considering the possibility of a multi-bit communication or storage system. In the phase-sensitive amplifier equations, formulated by Kath and collaborators, there are stable multiple pulse solutions and these can form the basis of a ternary (or higher) logic for the system. This could greatly enhance speed and efficiency. Computer experiments have now successfully predicted the robustness of these multiple pulses and their use as elements in a data storage or trasnmission system is very promising.

Jones' student Jean-Michel (a minority supported by Aasert grant) and

Jones have been working in close consultation with Kovanis at Philips Lab on developing a geometric view of the optically injected laser problem. An interesting source of complex behavior (chaos) has been uncovered. This complicated behavior is the result of parametric sweeping across a resonance. From the experimental and practical perspective this is a natural scenario and the possibility of implementing it experimentally has been discussed with Kovanis. This is potentially important in applications (for instance, communications) as the chaotic behavior can be precisely controlled and understood in terms of phase-shifting. Some recent work has revealed a direct source of chaotic behavior in the optically injected semiconductor laser equations.

Coupled NLS equations arise in the study of interacting, parallel optical fibers. Haller (with Rothos) has worked on the first approximation in which it is assumed that the coupling is weak among the fibers and hence a regime where a near-integrable set of partial differential equations is a good approximation. Invariant manifold theory and geometric singular perturbation theory along with detailed, long term estimates to construct multi-pulse solutions that describe jumping around the state in which all fibers become spatially independent are used. The solutions constructed form a rich family with different shapes in differemt fibers, thus we expect them to be useful in encoding information. As far as we know, this is the first geometric treatment of the dynamics of coupled NLS systems.